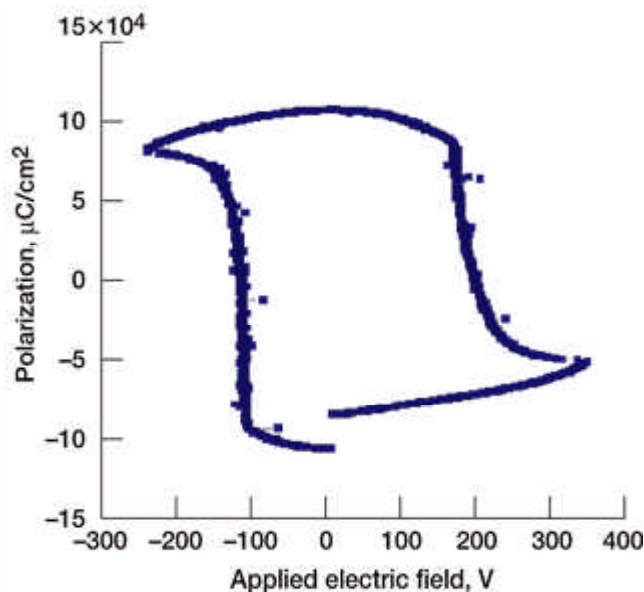


Processing Techniques Developed to Fabricate Lanthanum Titanate Piezoceramic Material for High-Temperature Smart Structures

Piezoelectric ceramic materials are potential candidates for use as actuators and sensors in intelligent gas turbine engines. For piezoceramics to be applied in gas turbine engines, they will have to be able to function in temperatures ranging from 1000 to 2500 °F. However, the maximum use temperature for state-of-the-art piezoceramic materials is on the order of 300 to 400 °F. Research activities have been initiated to develop high-temperature piezoceramic materials for gas turbine engine applications. Lanthanum titanate has been shown to have high-temperature piezoelectric properties with Curie temperatures of $T_c = 1500$ °C and use temperatures greater than 1000 °C (refs. 1 and 2). However, the fabrication of lanthanum titanate poses serious challenges because of the very high sintering temperatures required for densification.



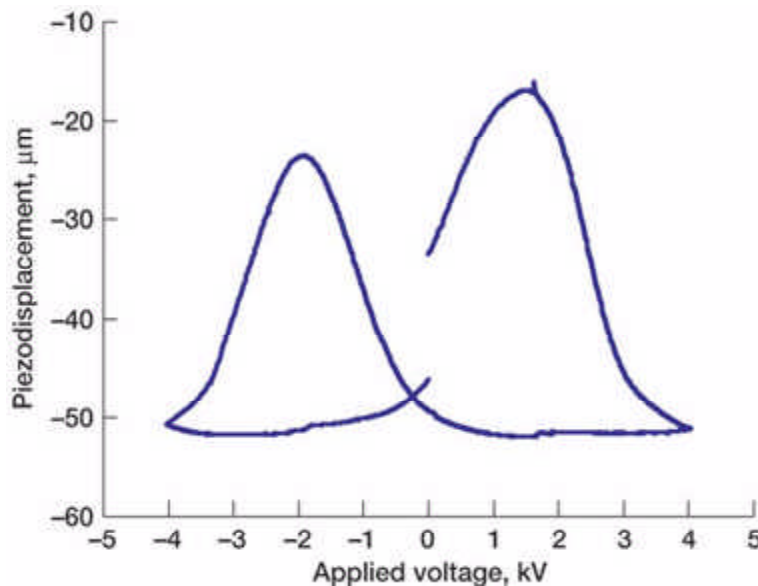
Electric polarization hysteresis of lanthanum titanate with 0.1 mol% of yttrium oxide taken at 360 °C.

The results of applying an external electric field to samples of lanthanum titanate with 0.1 mol% of yttrium oxide at elevated temperatures reveals hysteretic behavior; saturation occurs at 360 °C and 1.4 kV/cm.

Two different techniques have been developed at the NASA Glenn Research Center to

fabricate dense lanthanum titanate piezoceramic material. In one approach, lower sintering temperatures were achieved by adding yttrium oxide to commercially available lanthanum titanate powder. Addition of only 0.1 mol% yttrium oxide lowered the sintering temperature by as much as 300 °C, to just 1100 °C, and dense lanthanum titanate was produced by pressure-assisted sintering. The lanthanum titanate containing 0.1 mol% yttria exhibited excellent piezoelectric properties, as shown in the preceding graph, which displays a typical polarization response of lanthanum titanate as a function of applied electric field at 360 °C. In addition, this highly refractive material was able to sustain externally applied electric fields from 0.1 V/cm to 80 kV/cm without dielectric breakdown.

The second approach utilized the same commercially available powders but used an innovative sintering approach called differential sintering, which did not require any additive. Fully dense lanthanum titanate was produced by this technique, and the material did not degrade over time. The material exhibited excellent piezoelectric properties at room temperature, as shown in the following graph. The displacement was significantly higher than anticipated for a moderate applied electric field. Future efforts are planned to concentrate on optimizing the piezoelectric properties of lanthanum titanate at elevated temperatures.



Displacement of differentially sintered lanthanum titanate as a function of an externally applied electric field.

Optical methods were used to determine the displacement of lanthanum titanate sintered without press or additives. Measured displacement was found to be greater than anticipated on the basis of literature values.

References

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2. Kimura M., et al.: Electro Optic and Piezoelectric Properties of $\text{La}_2\text{Ti}_2\text{O}_7$ Single-Crystal. Jpn. J. Appl. Phys., vol. 11, no. 6, 1972, p. 904.

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